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GEOLOGICAL ACTIVITY OF MICROBES

Acad B. L. Isachenko (deceased).

Undoubtedly one of the most important factors in the Earth's history are microorganisms. They are detected in a fossil state in the most ancient terrestrial layers, starting with the Pre-cambrian where they have been preserved, like vestiges of higher plants, in the form of impressions. However, the study of microorganisms is much more complicated than that of higher plants, because vestiges of higher plants enable us to establish their type, while microorganisms are externally similar, although differing essentially in their physiological properties and processes. Therefore we can judge the former activity of microorganisms only by the results of their work, and we have no reasons to doubt the results of this activity. Let us discuss examples.

By analogy with recent decomposition of vegetable remains or with deposition of calcium carbonate (limestone), we may conclude that these processes proceeded in the same way during remote eras, differing maybe only in rate of speed. Depending on external conditions the activity of microorganisms could be accelerated or slowed down, as observed nowadays: for comparatively high temperatures favorable for microorganisma, organic substances decompose faster than at low temperatures as may be seen in arctic countries where low temperatures hinder decompositions and favor the preservation of corpses (for example, of once living mammoths). Similarly, higher or lower humidity, stronger or weaker concentration of salt in water - among many other factors - affect the work of microorganisms, varying only in rate of speed. Therefore, in attempting to clarify the role of the smallest organisms in geological processes, grandiose in their magnitude, it is necessary to take into account such complexities as the changing living organism producing the process. The variations in media and organisms are inseparably bound together in nature.

Data gathered by geologists establish noticeable traces of microorganisms among Pre-cambrian layers, and some investigators even claim that they have succeeded in reviving these microorganisms and have observed their development in cultures.

During the Pre-cambrian limestone aquatic plants flourished greatly to form later rocks laid down. In these rocks we may detect calciferous bodies, so-called oolites, which had been produced by bacteria. Oolites in ancient terrestrial layers, besides other remains, may serve as proof of the existence of bacteria during the early Pre-cambrian.

Among organisms appearing early in the Earth's development autotrophic organisms were probably predominant, forming organic substances from inorganic matter. Such organisms could be (a) colorless bacteria developing without light and subsiding on scarce inorganic salts, and (b) green chlorophyllous algae developing in presence of inorganic salts only but requiring sunlight. These two groups of organisms, bacteria and algae, are probably the Earth's most ancient inhabitants.

When provided with favorable conditions, bacteria develop unusually rapidly. According to some investigations (Zenkevich, 1930), bacteria form an organic mass of outstanding magnitude, surpassing the production of all other organisms; thus bacteria appear to be probably the most important factor governing the accumulation of organic matter on the Earth. It is not known whether this accumulation has always been great; it could be more or less in various locations. Independently of these events, however, organic matter accumulated and bacteria underwent evolution and acquired the ability to assimilate organic substances.

The destruction of organic matter by bacteria advanced with their successive ecquisition of this new property, but not with such intensity as happens now. Therefore organic matter was deposited in great quantities. The thriving autotrophic algae enriched the accumulating organic mass; on the other hand, the bacteria adjusted themselves to the new food sources, but had not as yet propagated fast enough to decompose, (with present-day vigor, all the organic matter forming).

Locations where organic fauna thrived the best were mainly the shallow portions seas and oceans, bays, lagoons, and estuaries. It may be observed at present that such secluded locations are consipicuous for their prevalence and sometimes for the rich variety of the organisms inhabiting them.

Therefore, the shore regions of seas and oceans were probably the scenes of most activity of the microorganisms and it is there that we should look for the most explicit traces of their past life. Organic matter massed in bays and lagoons should decompose under the effect of bacteria and form various decay products.

Let us dwell on one product of decay; namely, hydrogen sulfide. This gas is poisonous and living organisms perish if it exceeds several cm^3 per liter in air. Hydrogen sulfide forms in seas, estuaries and salt lakes, where it forms ferrous sulfide by combining with ferrous salts of muddy deposits, thus imparting a black color to the mud.

The amount of hydrogen sulfide is considerable in the depths of the Black Sea (6 cm^3/liter). Such water is deleterious to the fish life and other marine animals, which are able to live in this sea only in its upper layers, not below 150-200 meters, while the deep sea, its depth reaching 2000 meters, is lifeless. This is the world of bacteria, inhabiting the bottom and the deep layers. The formation of hydrogen sulfide proceeds during regeneration of sulfurous salts of sea water.

Besides in the Black Sea, hydrogen sulfide may be found on the Murmansk shores in fjords, where it prevents fishes from entering the bay. It may also be found in the Caspian Sea.

When hydrogen sulfide is acidified by oxygen in the upper layers of water or by a special group of bacteria, powderous sulfur is deposited on shores. Recent deposits provide evidence that sulfurous locations are results of various prolonged processes, during which regenerating and oxidizing processes alternate in a certain succession. The oxidizing energy of microorganisms is rather strong and should not be disregarded in processes connected with the transformation of sulfur, while the regeneration of sulfate compounds without the intermediacy of bacteria is unknown.

Therefore the sulfur sources of the Caucasus, Middle Asia, North America, Sicily and of other locations should be considered as results of biochemical processes that originated in the shore regions of once existing seas. Where geological data indicate boundaries of marine pools and where deposits of salt were likely to precipitate, we may expect to find sulfur. Associated with deposits of dead organisms, mostly algae, in shallow parts of former seas is another useful mineral, petroleum. The modern concept of the origin of petroleum considers it as the result of activity of microorganisms decomposing deposits of organic matter buried in remote geological eras. We do not posses exact data on locations where petroleum formed and opinions differ on this subject. Some people assume that the petroleum formations are connected with sea depths and basins contaminated with hydrogen sulfide, other associate petroleum with fresh water and saltish reservoirs of the lagoon type.

Research by Isachenko of purple sulfur bacteria, ejected on the Earth's surface from 2000 meter depths, enable us to consider these bacteria as reactive forms, probably buried in remote aras, possibly simultaneously with vegetable deposits, as it is possible to observe now on shores of estuaries and salt lakes. Algae precipitated on the bottom of water reservoirs were covered with deposits, under which various bacterial processes proceeded, resulting in transformations of the vegetable substances under the constantly growing pressure of fresh deposits. That these processes proceeded just this way may be seen from observations of recent water reservoirs.

It would not be too farfetched to assume that deposits of salts and sulfurs, as well as petroleum accumulations, are the products of marine life which underwent complex transformations (metamorphosis) and displacements (migrations). As a result of these processes, petroleum, e.g., because of its fluidity and tectonic processes, may have finally accumulated far from its original location where it had been formed. In general, according to the modern point of view, the formation of petroleum is mainly a biochemical process.

Microbiological data give the impression that differences in the chemical composition of petroleum are due to the work of bacteria. Some of them destroy paraffins; others destroy kerosene, thus depriving petroleum of one of its valuable properties, but contributing to the formation of medically useful naphthalene; and still others destroy sulfates of petroleum, thus desulfurizing it, etc. Therefore in every stage of formation of petroleum we may find traces of the presence of bacteria and of their activity.

Details involving the formation of petroleum and the role of various groups of bacteria in this most complicated process are not yet entirely clarified and many efforts of geologists and microbiologists will still be required to solve this problem.

The main part in the study of the biological character of the origin of petroleum was done until recently by Soviet scientists. The Baku oil wells ejecting thousands of tons of petroleum and water from below the petroleum layer, were investigated by microbiologists of the Azerbaydzhan Petroleum Institute (Ginzburg-Karagichev, Maliyants, Reynfeld) in accordance with Professor Ushinskiy's project. These investigations, far surpassing foreign ones, gave valuable information on the distribution of bacteria, differing in their physiological properties, in the depths.

Hence, according to modern views, the formation of petroleum is closely tied up with the activity of microorganisms which destroy the organic matter deposited in water reservoirs during remote geological times. The materials basic to the formation of petroleum were probably vegetable organisms in the form of small single-cell algae and tiny animals. Their tiny masses are deposited when dying, but at the present time their total weight is in the hundreds of thousands tons. Exactly similar accumulations of organic matter occurred previously in fresh water and saltish reservoir of the lagoon type. Possibly petroleum originated also in deep water deposits, contaminated by hydrogen sulfide, as observed in the Black Sea.

In order to complete the picture of the work proceeding continuously for millions of years and tightly bound up with the activity of bacteria, we should mention the formation of carbonates, especially calcium carbonate. The activity of bacteria that causes the formation of rock, the so-called travertine, may be seen in Pyatigorsk. It was experimentally established (by Isachenko) that water flowing out of the underground and containing carbonates is a rich source of carbonate precipitation. Stones, plant branches, the most diverse living or dead objects, are coated with calcium carbonate, as if they were accumulators of the tiniest particles of carbonates.

While studying under the microscope the first instants of deposition of calcium carbonate, we may see how it coats the bacterial cell, forming during this stage rod-like bodies, which progressively will make up round bodies of various sizes or oolite bodies that look like dumbbells. These bodies may, as mentioned in the beginning of this article, provide a proof of the biochemical origin of Pre-devonian deposits.

Finally we should point out that studies of the structure of the Bahama Isles near Florida have revealed that they are built of calcium carbonate, and that bacteria named Bacterium Calcis were found in the sea water. This bacteria has the ability to deposit calcium carbonate. If such a process went on for millions of years, numbers to which geologists are accustomed, then the calcium deposited by the bacteria should finally accumulate in quantities sufficient to serve as materials for formation of a group of islands. From these examples we may see once more the tremendous results of continuous activity for millions of years of bacteria found in great amounts in sea water.

Infinitely small, but extremely energetic, the bacteria has been a powerful factor in our planet's history in changing the face of the Earth.

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